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Argonne NATIONAL LABORATORY

Summary of Operations and Performance of the Utica Aquifer and North Lake Basin Wetlands Restoration Project in December 2005–November 2006

Environmental Science Division

USDA United States Department of Agriculture

Work sponsored by Commodity Credit Corporation, United States Department of Agriculture

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by
Applied Geosciences and Environmental Management Section
Environmental Science Division, Argonne National Laboratory

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Notation

BGL	below ground level
CCC	Commodity Credit Corporation
°F	degree(s) Fahrenheit
ft	foot (feet)
gal	gallon(s)
gpm	gallon(s) per minute
GWEX	groundwater extraction
hr	hour(s)
in.	inch(es)
kg	kilogram(s)
µg/L	microgram(s) per liter
mph	mile(s) per hour
mg/L	milligram(s) per liter
MW	monitoring well
NDEQ	Nebraska Department of Environmental Quality
NGPC	Nebraska Game and Parks Commission
NPDES	National Pollutant Discharge Elimination System
USDA	U.S. Department of Agriculture
VOC	volatile organic compound

Summary of Operations and Performance of the Utica Aquifer and North Lake Basin Wetlands Restoration Project in December 2005–November 2006

1 Introduction

This document summarizes the performance of the groundwater restoration systems installed by the Commodity Credit Corporation of the U.S. Department of Agriculture (CCC/USDA) at the former CCC/USDA grain storage facility in Utica, Nebraska, during the second year of system operation, from December 1, 2005, until November 31, 2006.

In the project at Utica, the CCC/USDA is cooperating with multiple state and federal agencies to remove carbon tetrachloride contamination from a shallow aquifer underlying the town and to provide supplemental treated groundwater for use in the restoration of a nearby wetlands area. Argonne National Laboratory has assisted the CCC/USDA by providing technical oversight for the aquifer restoration effort and facilities during this review period.

This document presents overviews of the aquifer restoration facilities (Section 2) and system operations (Section 3), then describes groundwater production results (Section 4), groundwater treatment results (Section 5), and associated groundwater monitoring, system modifications, and costs during the review period (Section 6). Section 7 summarizes the present year of operation.

2 Overview of the Aquifer Restoration Facilities at Utica

The principal components of the groundwater restoration systems at Utica are shown in Figure 2.1. The facilities consist of two main operating units, as described below. The facilities include four groundwater extraction (GWEX) wells. Table 2.1 summarizes construction details for these wells.

2.1 Wells GWEX1–GWEX3 and the Spray Irrigation Treatment Units

Extraction wells GWEX1–GWEX3, located in the northern portion of the town, are used to extract contaminated groundwater from the upgradient portion of the contaminant plume. These wells are linked by a distribution system that selectively carries untreated groundwater to either of two discharge points in the northern and southern subbasins of the North Lake Basin Wildlife Management Area (Figure 2.1). At each discharge point, the water is treated to remove carbon tetrachloride by using a custom spray irrigation treatment unit (Figure 2.2). The three extraction wells are operated simultaneously to maintain a critical operating pressure at each treatment unit.

Wells GWEX1–GWEX3 are operated intermittently during the year, subject to local weather conditions and in consultation with the Nebraska Game and Parks Commission (NGPC). NGPC owns most of the property occupied by the wetlands and has administrative and technical responsibility for management of the wildlife area.

TABLE 2.1 Summary of construction details for GWEX wells at Utica.

	Depth (ft BGL)			
Well	Depth	Screen Interval	Gravel Pack Interval	Casing Diameter (in.)
GWEX1	132	106–126	97–132	8
GWEX2	148	110–145	106–148	8
GWEX3	146	105–140	101–146	8
GWEX4	150	115–145	110–150	6

2.2 Well GWEX4 and the Conventional Air Stripper

Extraction well GWEX4 is located near the downgradient toe of the carbon tetrachloride plume and is operated continuously as a containment well. Groundwater produced from GWEX4 is treated by using a conventional (shallow-tray) air stripping technique, and the effluent is discharged to the surface for reinfiltration into the shallow Utica aquifer.

2.3 Monitoring Well Network

A network of seven permanent monitoring points has been established at Utica (Figure 2.1). Wells SB48, SB71, and SB72 were constructed during the early phases of the investigations at Utica. These wells were intended primarily for the measurement of groundwater levels; they do not penetrate the more contaminated zones of the groundwater column identified in detailed vertical-profile sampling (Argonne 2000). To improve monitoring coverage, additional wells MW1–MW4 were installed at strategic locations along the plume migration pathway in August 2005.

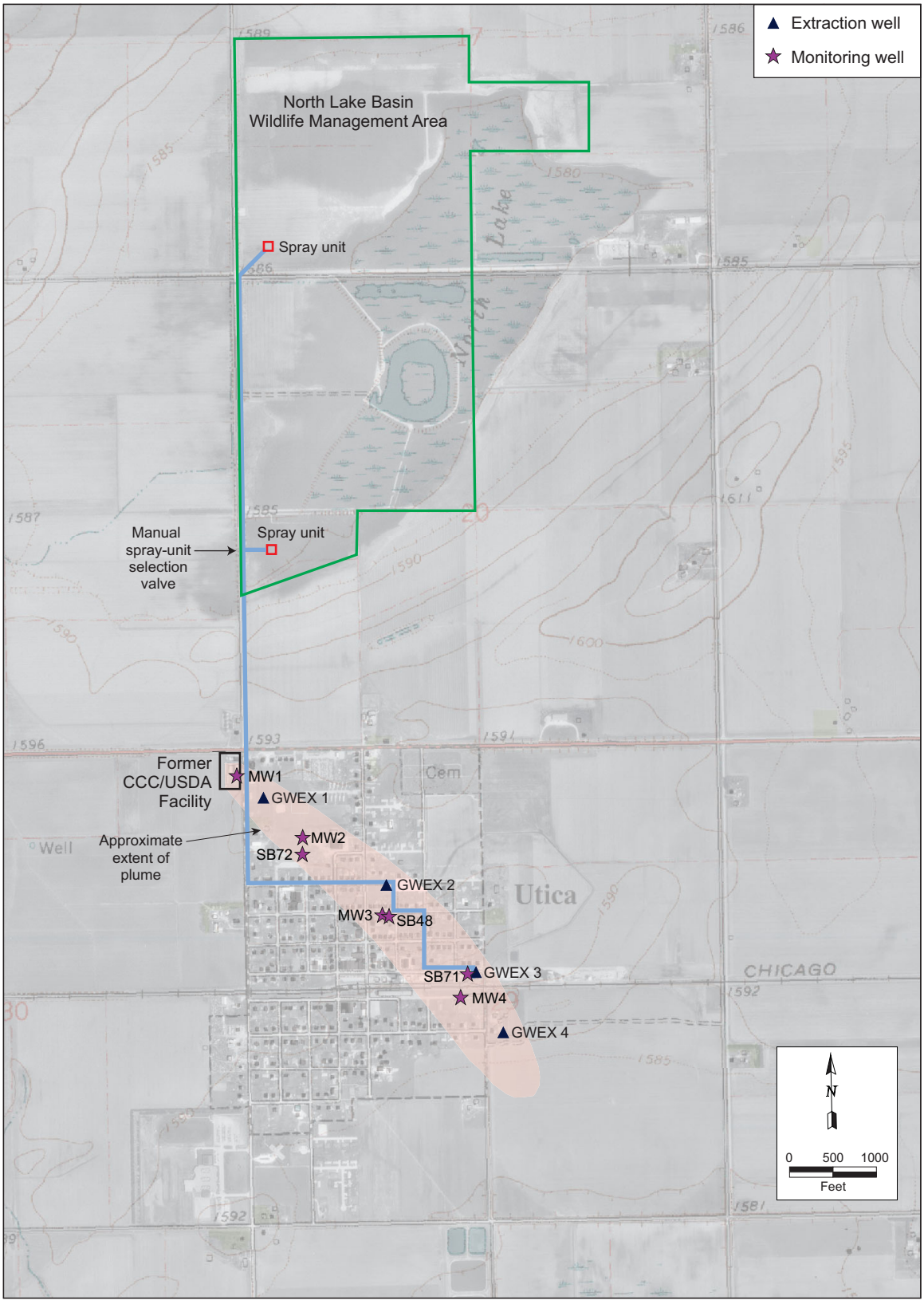

FIGURE 2.1 Locations of the restoration facilities, contaminant plume, and permanent monitoring wells at Utica.

FIGURE 2.2 Spray irrigation unit in operation at Utica.

3 Overview of System Operations

3.1 Operation of Wells GWEX1–GWEX3 and the Spray Irrigation Treatment Units

Wells GWEX1–GWEX3 and the spray irrigation treatment units were operated intermittently, under automated control, during 11 of the 12 months in the review period. The daily operation of the spray treatment units is governed primarily by weather conditions; to ensure effective removal of the carbon tetrachloride and to prevent excessive drift of the resulting spray discharge, a minimum air temperature of 40°F and sustained winds of less than 20 mph are required for operation. The extraction wells and treatment units did not operate in December 2005 because of inclement weather conditions.

Treated groundwater from the spray irrigation systems was selectively routed to both the north and south subbasins at the request of the NGPC. Groundwater was discharged exclusively to the north subbasin during the winter of 2005 and spring of 2006. In late May 2006, two of the three spray irrigation spans at the north subbasin were heavily damaged by storms and collapsed (Figures 3.1–3.2), temporarily preventing the use of these units. With the permission of the NGPC, groundwater was therefore routed to the south subbasin spray treatment units during June–October 2006. Repairs at the north spray treatment site were completed in late October 2006, and discharge to the north subbasin was resumed in November 2006.

Unexpected shutdowns of GWEX1–GWEX3 and the spray treatment units occurred sporadically throughout the first year of operation of these systems (Argonne 2005) and continued into the current review period. The cause of these incidents was traced to faulty float switches that had been installed originally at both the north and south spray treatment sites. The switches control the drainage of water from the spans when they are not in operation. Since the switches were replaced in November 2006, no further service interruptions of this type have occurred.

3.2 Operation of Well GWEX4 and the Conventional Air Stripper

Well GWEX4 and the associated air stripper operated continuously during the review period. The only exception was one brief interruption on July 27–28, 2006, when the equipment was temporarily shut down to permit the local utility company to replace a line transformer that serves the CCC/USDA treatment facility. Failure of the transformer was caused by faulty supply

wiring, previously installed by the utility company, that had worn against a tree branch. No damage to CCC/USDA equipment occurred.

Treated groundwater from well GWEX4 is discharged to an open ditch that serves as part of Utica's storm drainage system. The ditch borders a county road leading eastward from the town, as well as an adjacent private farm property. During the review period, Argonne received no reports of drainage or other problems associated with the discharge from GWEX4.

FIGURE 3.1 Damage to the western and central irrigation spans at the northern spray treatment site, caused by storms at Utica in May 2006, in a view looking east from the site access road.

FIGURE 3.2 Damage to the western and central irrigation spans at the northern spray treatment site caused by storms at Utica in May 2006, in a view looking north from the southern edge of the treatment site.

4 Groundwater Production Results

The volumes of groundwater extracted from the Utica aquifer, treated, and discharged are summarized in Table 4.1.

4.1 Production by Wells GWEX1–GWEX3

Wells GWEX1–GWEX3 are equipped with electronically controlled pump drive units linked to digital flow meters that automatically and continuously adjust the flow from each well

TABLE 4.1 GWEX operation and groundwater production data for the 2005–2006 review period at Utica.

	Groundwater Produced by Wells GWEX1–GWEX3[a] (gal)			Operating Time	Volume Discharged to Wetlands (gal)		GWEX4	
Month	GWEX1	GWEX2	GWEX3	GWEX1–3[b] (hr)	North	South	Groundwater Produced (gal)	Operating Time (days)
Dec 05	–[c]	–	–	–	–	–	2,460,410	31
Jan 06	124,200	491,100	308,100	32.2	923,400	–	2,527,090	31
Feb 06	267,100	1,060,200	664,800	87.1	1,992,100	–	2,242,800	28
Mar 06	196,600	779,100	488,700	65.1	1,464,400	–	2,514,930	31
Apr 06	403,100	1,603,700	1,005,700	198.2	3,012,500	–	2,418,170	30
May 06	1,439,400	5,728,400	3,592,500	530.4	10,760,300	–	2,421,240	31
Jun 06	1,310,700	5,214,500	3,272,400	459.4	–	9,797,600	2,455,970	30
Jul 06	2,249,600	8,963,200	5,620,000	748.0	–	16,832,800	2,409,780	29
Aug 06	1,977,900	7,875,400	4,939,400	657.0	–	14,792,700	2,598,810	31
Sept 06	1,812,200	7,210,500	4,522,200	602.0	–	13,544,900	2,391,530	30
Oct 06	819,300	3,269,500	2,042,600	272.5	–	6,131,400	2,598,880	31
Nov 06	681,200	2,735,000	1,697,200	227.3	5,113,400	–	2,544,400	30
TOTAL	11,281,300	44,930,600	28,153,600	3,879.2	23,266,100	61,099,400	29,584,010	363

[a] Combined total production: 113,949,510 gal. Total production to wetlands: 84,365,500 gal.

[b] Wells GWEX1-GWEX3 operate simultaneously.

[c] Unit not in operation.

to maintain user-specified pumping rates. During this review period, the programmed flow rates for these wells were as follows:

- GWEX1, 50 gpm
- GWEX2, 200–205 gpm
- GWEX3, 125 gpm

The selected rates were achieved, within ±1 gpm, throughout the review period.

Wells GWEX1–GWEX3 were pumped for approximately 3,879 hr during the review period, and they discharged approximately 84.3 million gallons (259 acre-feet) of treated water to the North Lake Basin wetlands. The wells operated almost continuously throughout the summer months and into the early fall. Approximately 72% of the total production was routed to the southern wetlands subbasin, with the approval of the NGPC.

4.2 Production by Well GWEX4

Measured groundwater pumping rates (determined from an inline flow meter) at GWEX4 remained relatively stable, ranging from approximately 55 gpm to 59 gpm, throughout the review period. No adjustments were required to maintain these rates. The volume of groundwater pumped in any one complete month (Table 4.1) ranged from about 2.2 million gallons to 2.6 million gallons. Approximately 29.6 million gallons (90.8 acre-feet) of groundwater was treated and discharged during the review period, at a net average pumping rate of 56.7 gpm.

5 Groundwater Treatment Results

Treated groundwater at Utica is discharged under a National Pollutant Discharge Elimination System (NPDES) Permit, number NE0137456, issued by the Nebraska Department of Environmental Quality (NDEQ) on October 1, 2004.

To comply with the NPDES permit, samples of treated groundwater are collected monthly

- At the outlet of the air stripping unit at GWEX4 and
- From the spray discharge at each of the irrigation treatment units (during months of operation).

The samples are analyzed to determine the residual concentrations of carbon tetrachloride in the treated groundwater and the pH of the effluent. The results of these analyses are reported to the NDEQ quarterly.

The discharges of treated groundwater at Utica are considered by the NDEQ to contribute to the surface waters of the state. On this basis, NDEQ has specified the following compliance limits for the outfall from each treatment unit:

- A target maximum residual carbon tetrachloride concentration of 44.2 μg/L
- An acceptable pH range of 6.5 to 9.0

In conjunction with the compliance sampling, Argonne collects monthly samples of the untreated groundwater from each extraction well. The samples are analyzed for volatile organic compounds (VOCs) to enable estimation of the following:

- Carbon tetrachloride removal efficiencies for the treatment units
- Quantities of carbon tetrachloride removed from the contaminated aquifer

The results of the sampling and analyses during the review period are summarized in Tables 5.1 and 5.2.

5.1 Results for Wells GWEX1–GWEX3, with Treatment by Spray Irrigation

The concentrations of carbon tetrachloride found in the untreated groundwater from extraction wells GWEX2 and GWEX3 decreased significantly during the review period (Table 5.1). The decrease occurred in apparent association with the onset of almost continuous pumping that began in June 2006 and continued through the summer and fall. Carbon tetrachloride levels subsequently remained fairly stable at GWEX2 and GWEX3 after midsummer. From December 2005 through June 2006, carbon tetrachloride concentrations at GWEX2 ranged from 85 µg/L to 146 µg/L, while at GWEX3 the levels ranged from 129 µg/L to 235 µg/L. From July through November 2006, the observed carbon tetrachloride levels at GWEX2 ranged from 49 µg/L to 77 µg/L, while those at GWEX3 ranged from 66 µg/L to 98 µg/L.

Observed carbon tetrachloride levels at upgradient extraction well GWEX1 increased during the period of more sustained pumping in July–November 2006. Carbon tetrachloride concentrations at this well ranged from 25 µg/L to 47 µg/L from December 2005 through June 2006, and from 44 µg/L to 85 µg/L during the later part of the review period.

The groundwater produced from wells GWEX1–GWEX3 is combined into a single stream for conveyance to the wetlands via a common pipeline. This combined flow is also sampled monthly as an indicator of the weighted average concentration of carbon tetrachloride in the untreated groundwater supplied to the spray irrigation treatment units. The measured concentrations in the combined flow varied from 71 µg/L to 139 µg/L during the monitoring period. The concentrations observed in the combined flow during the current review period were generally similar to those observed in 2004-2005, though somewhat more variable.

Treated groundwater sprayed from the irrigation units is collected for analysis at the following four locations at the treatment site during each sampling event:

- Beneath the center point of the “west” irrigation span
- Beneath the center point of the “center” irrigation span

TABLE 5.1 Analytical results for carbon tetrachloride in untreated groundwater samples and treated effluent samples.

	Carbon Tetrachloride Concentration (µg/L)													
	GWEX1–GWEX3 Untreated				North Spray Unit Effluent				South Spray Unit Effluent					
Month	GWEX1	GWEX2	GWEX3	Mixed[a]	West[b]	Center[b]	East[b]	Max[c]	West[b]	Center[b]	East[b]	Max[c]	GWEX4 Untreated	Stripper Effluent
Dec 05	–[d]	–	–	–	–	–	–	–	–	–	–	–	51	ND[e]
Jan 06	47	97	153	109	6.9	1.4	1.0	1.8–2.0[f]	–	–	–	–	47–56	ND
Feb 06	27	85	156	81	–	0.8J[g]	0.2J	0.3J–0.8J	–	–	–	–	52–58	ND
Mar 06	39–40	117	161	139	1.6	0.7J	0.9J–1.2	0.4J	–	–	–	–	46–47	ND
Apr 06	37–38	146	203	107–125	2.0	0.5J	3.2	0.6J	–	–	–	–	52–70	ND
May 06	25	96	221–235	124	0.8J	0.5J	0.4J	0.5J	–	–	–	–	50–58	ND
Jun 06	47	109	129–136	125	–	–	–	–	3.1–3.3	1.2	ND	0.4J	47	ND
Jul 06	63	65–77	71	76	–	–	–	–	ND	2.0	ND–0.5J	ND	34	ND
Aug 06	76	77	98	71–73	–	–	–	–	ND	ND	ND	ND	40–44	ND
Sep 06	63	64–66	76	79	–	–	–	–	1.8	0.3J	0.4J	0.4J	32–34	ND
Oct 06	44–85	49	66	90	–	–	–	–	1.4	ND	0.6J	0.3J–0.4J	35–43	ND
Nov 06	68	75–76	77	73	1.4	0.2J	ND	0.2J–0.3J	–	–	–	–	26–28	ND

[a] Analytical results for samples from the combined flows of GWEX1–GWEX3.

[b] Samples of spray collected below the center point of the respective irrigation span.

[c] Samples of spray collected at the estimated location of maximum spray outfall.

[d] Unit not in operation.

[e] ND, not detected at a method detection limit of 0.1 µg/L.

[f] Ranges of values represent both primary samples and quality control replicates and duplicates.

[g] Qualifier J indicates an estimated concentration below the quantitation limit of 1.0 µg/L for the purge-and-trap method.

TABLE 5.2 Values for pH in untreated groundwater samples and treated effluent samples.

	pH							
	GWEX1–GWEX3 Untreated				North Spray Unit[b]	South Spray Unit[b]	GWEX4 Untreated	Stripper Effluent
Month	GWEX1	GWEX2	GWEX3	Mixed[a]				
Dec 05	–[c]	–	–	–	–	–	6.58–6.78[d]	7.72–8.15
Jan 06	7.27	7.06	6.99	7.02	7.50–8.19	–	7.13–7.35	8.48–8.58
Feb 06	7.11–7.17	7.12–7.18	6.99–7.02	7.01–7.12	7.48–7.68	–	7.02–7.05	8.32–8.35
Mar 06	6.95–7.15	6.81–6.94	6.72–6.82	6.89–6.90	7.77–8.11	–	6.49–6.68	7.79–7.94
Apr 06	7.35–7.37	6.81–6.90	6.72–6.76	6.79–6.84	7.54–7.84	–	6.74–6.80	8.24–8.33
May 06	7.57–7.63	7.37–7.54	7.41–7.48	7.41–7.55	7.88–8.14	–	7.12–7.18	8.24–8.32
Jun 06	6.86–6.95	6.60–6.69	6.56–6.65	6.84–6.90	–	7.10–7.46	6.27–6.31	7.50–7.65
Jul 06	7.36–7.39	7.27–7.32	7.22–7.29	7.16–7.24	–	7.75–8.02	6.81–6.84	7.63–7.91
Aug 06	7.43–7.68	7.63–7.66	7.73–7.79	7.51–7.52	–	8.23–8.32	7.23–7.28	8.25–8.34
Sep 06	7.11–7.23	7.05–7.06	7.09–7.17	7.04–7.20	–	8.07–8.20	6.71–6.75	8.05–8.08
Oct 06	7.25–7.31	6.78–7.04	7.00–7.20	7.15–7.20	–	7.89–7.97	6.58–6.65	7.91–7.98
Nov 06	6.80–6.85	6.87–7.03	6.83–6.85	6.91	7.85–8.02	–	6.71–6.79	8.14–8.15

[a] Ranges of values for multiple measurements of the combined flows of GWEX1-GWEX3.

[b] Ranges of values for spray samples collected at multiple locations at the discharge site.

[c] Unit not in operation.

[d] Ranges of values for multiple measurements at this location.

- Beneath the center point of the “east” irrigation span

- At a fourth location visually chosen to reflect the estimated site of maximum spray outfall (“max” value; position varying from month to month; based on prevailing wind and spray conditions at the time of sampling)

The results summarized in Table 5.1 show that, with only one exception, the concentrations of all spray samples collected during the review period were below the maximum contaminant level of 5.0 µg/L promulgated by the U.S. Environmental Protection Agency for carbon tetrachloride in drinking water. The *maximum* carbon tetrachloride level identified for a single sample in spray discharged from the irrigation treatment units was 6.9 µg/L. The *average* concentration of carbon tetrachloride in the treated groundwater discharged to the wetlands was 0.91 µg/L. The concentrations of carbon tetrachloride in all spray samples were below the maximum target concentration (44.2 µg/L) allowed under the NPDES permit, by roughly an order of magnitude.

The results of the groundwater and spray sample analyses suggest the following *minimum carbon tetrachloride removal efficiency values* for the spray irrigation treatment process:

- More than 93% (based on data for individual samples)

- Approximately 99% (based on the average concentration delivered to the wetlands during the review period)

The results of pH measurements recorded for samples of the treated spray discharge are presented in Table 5.2. In all cases, the observed pH levels (7.10 to 8.32) were within the acceptable range (6.5 to 9.0) specified under the NPDES permit.

5.2 Results for Well GWEX4, with Treatment by Air Stripping

Carbon tetrachloride concentrations in the untreated groundwater produced by GWEX4 (Table 5.1) were relatively stable (46 µg/L to 70 µg/L) from December 2005 through June 2006. As at GWEX1–GWEX3, reduced concentrations (26 µg/L to 44 µg/L) were also detected at this location during the latter part of the review period, in apparent conjunction with the sustained pumping at wells GWEX1–GWEX3 during the summer and fall. Carbon tetrachloride was not detected in the effluent from the air stripping unit throughout the review period, indicating a carbon tetrachloride removal efficiency of > 99% for this process. Measured pH levels in all samples of the air stripper effluent (7.50 to 8.58; Table 5.2) were within the acceptable range (6.5 to 9.0) specified under the NPDES permit.

5.3 Estimated Removal of Carbon Tetrachloride from the Utica Aquifer

The groundwater production and carbon tetrachloride concentration data presented in Tables 4.1 and 5.1, respectively, can be used to estimate the total quantity of carbon tetrachloride extracted by wells GWEX1–GWEX4 from December 1, 2005, to November 30, 2006. The results of these calculations, summarized in Table 5.3, indicate that approximately 34 kg (5.6 gal) of carbon tetrachloride was removed from the Utica aquifer during the 2005–2006 review period. For comparison, approximately 23 kg (3.8 gal) of carbon tetrachloride was removed during 2004–2005.

TABLE 5.3 Estimation of carbon tetrachloride removed from the Utica aquifer.[a]

	GWEX1–GWEX3				GWEX4			
			Carbon Tetrachloride				Carbon Tetrachloride	
	Groundwater Extracted			Calculated Amount	Groundwater Extracted			Calculated Amount
Month	(gal)	(L)	Concentration[b] (µg/L)	Removed (kg)	(gal)	(L)	Concentration (µg/L)	Removed (kg)
Dec 05	–[c]	–	–	–	2460410	9315112	51	0.5
Jan 06	923400	3495992.4	109	0.4	2527090	9567563	52	0.5
Feb 06	1992100	7542090.6	81	0.6	2242800	8491241	55	0.5
Mar 06	1464400	5544218.4	139	0.8	2514930	9521525	47	0.4
Apr 06	3012500	11405325	116	1.3	2418170	9155192	61	0.6
May 06	10760300	40738495.8	124	5.1	2421240	9166815	54	0.5
Jun 06	9797600	37093713.6	125	4.6	2455970	9298302	47	0.4
Jul 06	16832800	63728980.8	76	4.8	2409780	9123427	34	0.3
Aug 06	14792700	56005162.2	72	4.0	2598810	9839095	42	0.4
Sep 06	13544900	51280991.4	79	4.1	2391530	9054333	33	0.3
Oct 06	6131400	23213480.4	90	2.1	2598880	9839360	39	0.4
Nov 06	5113400	19359332.4	73	1.4	2544400	9633098	27	0.3
TOTAL				29.2				5.0

[a] Total carbon tetrachloride removed from the aquifer: 34.2 kg.

[b] Concentration in untreated samples of the combined flow from wells GWEX1–GWEX3.

[c] Unit not in operation.

6 Operation, Maintenance, and System Modifications

6.1 Wells GWEX1–GWEX3 and the Spray Irrigation Treatment Units

Maintenance required on extraction wells GWEX1–GWEX3 during the review period involved adjustment of the pump motor variable-frequency drives at wells GWEX1 and GWEX3 to eliminate the sporadic occurrence of false alarm (electrical load imbalance) conditions.

Maintenance and repairs for the spray irrigation units and the groundwater delivery system included the following:

- Periodic field inspection of the units and all operating parameters.

- Seasonal mowing along the gravel access roads and pads at the north and south spray treatment sites.

- Reconstruction of the western and central irrigation spans at the north spray unit, to repair severe wind damage that occurred as a result of May storms.

- Replacement of the sump pump in the irrigation span drain-back vault at the north spray unit, due to an electrical fault.

- Periodic manual pumping of the drain-back vault at the north spray unit, to permit continued groundwater discharge to the north subbasin while the dedicated sump pump was inoperative.

- Repair of a leaking flange in the drain-back vault at the south spray unit and replacement of leaking check valves at both the north and south spray units.

- Replacement of incorrect water level float switches that had been installed at the north and south drain-back vaults during their original construction.

- Replacement of the external telephone modem at the well control building, which permits remote communication with the system's base station computer.

- Replacement of several cracked electrical box covers in the pavements along the delivery pipeline within Utica, at the request of the village Maintenance Department.

6.2 Well GWEX4 and the Air Stripping Unit

Well GWEX4 required no maintenance or repairs during the review period.

Maintenance of the shallow-tray air stripper was limited to replacement of an electrical solenoid on the bypass drain valve line.

6.3 Sampling of Monitoring Wells

Table 6.1 summarizes construction data for the monitoring wells, as well as the results of quarterly groundwater sampling and analyses for VOCs since wells MW1–MW4 were installed in August 2005. The results indicate that the observed carbon tetrachloride concentrations in groundwater at MW1, MW2, and MW3 generally increased through the fall and winter of 2005

TABLE 6.1 Well construction data and analytical results for carbon tetrachloride in groundwater samples from the permanent monitoring wells.

	Depth (ft BGL)		Carbon Tetrachloride (μg/L)				
Well	Total	Screened Interval	Oct 05	Jan 06	Mar 06	Jul 06	Oct 06
SB48	98.5	83.5–93.5[a]	ND[b]	0.1J[c]	ND	ND	ND
SB71	94.2	84–94	0.3J	0.4J	0.3J	ND	ND
SB72	122.3	82.6–112.6	3.6	3.2–3.5	3.4	2.4–2.5	1.8
MW1	105	85–100	79.0	175.0	211.0	205.0	130.0
MW2	115	90–110	9.3	10.0	15.0	14.0	17.0
MW3	125	100–120	36.0	67.0	82.0	79.0	58.0
MW4	125	100–120	33.0–34.0	19–21	29.0	3.3	4.9

[a] Ranges of values include quality control samples.

[b] ND, not detected at a method detection limit of 0.1 μg/L.

[c] Qualifier J indicates an estimated concentration below the quantitation limit of 1.0 μg/L for the purge-and-trap method.

and spring of 2006, before effectively continuous seasonal pumping began at the site in June 2006. The observed contaminant concentrations at well MW4 were relatively stable throughout the period of observation prior to July 2006.

In apparent response to the onset of the more continuous pumping in June 2006, carbon tetrachloride levels declined at wells MW1, MW3, and MW4. In contrast, the observed concentrations at MW2 showed little change during the later half of 2006.

6.4 Evaluation of Groundwater Inorganic Geochemistry

In accord with the approved *Monitoring Plan* for Utica (Argonne 2004), samples of the untreated groundwater from individual extraction wells GWEX1–GWEX4, the combined flow from wells GWEX1–GWEX3 that is supplied to the spray irrigation treatment units, and the (treated) effluent from the air stripper at GWEX4 were collected in October 2006 and submitted for analyses of cation and anion concentrations. The results of the analyses are in Table 6.2, together with equivalent data obtained for these sampling locations upon start-up of the aquifer restoration program in November 2004. (No samples were collected for inorganic geochemical analyses in 2005.)

The October 2006 results indicate no substantial changes (since restoration began) in the geochemistry of the groundwater produced by the extraction wells, treated, and discharged to the surface near Utica and to the North Lake Basin Wetlands. Slight increases in the concentrations of calcium, sodium, and chloride (possible constituents of road salts), as well as nitrate, were observed for most of the sampling locations. An approximate doubling in the apparent concentration of sulfate (from ~ 34 mg/L in 2004 to ~ 64 mg/L in 2006) was observed in both the untreated and treated groundwater samples from well GWEX4 only.

The results of vertical-profile sampling previously conducted by Argonne (2000) generally identified decreasing concentrations of nitrate (in particular) with depth within the Utica aquifer. Wells GWEX1–GWEX4 are screened in the deeper portions of the aquifer. The observed increases in ionic concentrations in the produced water from the deeper portions of the aquifer (especially concentrations of calcium, sodium, chloride, and nitrate in water from wells GWEX1, GWEX2, and GWEX4) therefore suggest possible downward vertical redistribution of these species within the groundwater column in response to the extraction well pumping.

TABLE 6.2 Inorganic geochemical results for untreated groundwater samples from GWEX1–GWEX4 and treated effluent samples from GWEX4 in November 2004 and October 2006.

	Concentration (mg/L)											
	GWEX1		GWEX2		GWEX3		GWEX1–GWEX3		GWEX4 Untreated		GWEX4 Effluent	
Analyte	Nov. 2004	Oct. 2006	Nov. 2004	Oct. 2006	Nov. 2004	Oct. 2006	Nov. 2004	Oct. 2006	Nov. 2004	Oct. 2006	Nov. 2004	Oct. 2006
Total Alkalinity	–[a]	266	–	275	–	255	–	262	–	287	–	287
Aluminum	< 0.2[b]	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Calcium	67.6	84.9	78.6	87.5	92.8	89.4	82.2	96.9	89.4	109	85.7	106
Chloride	6.93	13.2	11.4	24.0	25.9	24.0	15.5	21.9	18.3	28.9	18.7	29.3
Iron	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Magnesium	11.6	13.0	13.4	13.6	16.2	13.9	14.3	15.1	14.8	17.0	14.8	16.5
Manganese	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015
Phosphate	0.363	0.305	0.777	0.307	0.391	0.299	0.218	0.311	0.332	0.293	< 0.2[b]	0.298
Phosphorus	0.285	0.273	0.285	0.279	0.264	0.318	0.279	0.287	0.278	0.255	0.283	0.275
Potassium	5.66	6.27	6.00	6.33	6.94	6.43	6.27	6.85	6.58	7.10	6.60	6.86
Silicon	16.8	17.0	17.1	16.5	17.9	16.5	17.4	17.0	17.6	17.3	17.7	16.8
Sodium	26.5	31.9	28.7	34.4	32.0	35.1	29.5	38.4	32.8	41.6	33.5	41.0
Sulfate	22.4	23.1	45.5	39.1	59.8	46.3	47.9	39.3	33.5	64.9	34.5	63.6
Zinc	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Nitrate (as N)	7.57	10.3	9.76	15.0	17.4	19.5	13.3	15.5	14.7	20.5	13.3	20.7
Nitrate-Nitrite N	7.91	9.24	9.62	14.7	18.2	17.6	12.3	15.5	14.1	20.8	14.1	20.5

[a] Sample not analyzed for this constituent.

[b] Analyte not identified at the analytical method detection limit indicated.

6.5 Operating and Maintenance Costs in 2005–2006

Operating and maintenance costs for this review period are summarized in Table 6.3. These costs include one-time expenses associated with the following:

- Reconstruction of the western and central irrigation spans and related system repairs at the north subbasin, to correct severe storm damage that occurred at the treatment site in May 2006.

- The installation of equipment that operates on the government-specific radio frequency, as part of the well control and telemetry system, in October 2005 (Argonne 2005) for which billing was not received until the current review period.

Aside from these two items, routine operating, support, monitoring, and oversight costs for the Utica project ($208,186) were significantly lower during the current review period than in the first year of operations at the site (2004–2005; $270,879).

TABLE 6.3 Summary of 2005–2006 operating and maintenance costs for the Utica restoration project

Item	Cost ($)
Routine Costs	
General Management	17,699
Logistics Support	74,713
Remediation Monitoring	110,546
Technical Oversight	5,228
SUBTOTAL	208,186
Non-routine Costs	
Irrigation Span Repairs	57,591
Radio Control System[a]	5,140
SUBTOTAL	62,731
TOTAL	270,916

[a] Costs for government-frequency radio modems installed late in the 2004–2005 review period.

7 Summary

A combined total of approximately 114 million gallons of contaminated groundwater was extracted and treated during the operation of the aquifer restoration systems at Utica from December 1, 2005, to November 30, 2006. Approximately 74% of the total volume treated (259 acre-feet) was used to supplement the natural water entering the North Lake Basin Wildlife Management Area.

Groundwater modeling studies performed by Argonne during the development of the aquifer restoration approach for Utica (Argonne 2000) indicated that, on average, the extraction of approximately 97 million gallons of groundwater per year would be required to achieve cleanup of the aquifer in approximately 10–15 years. The actual groundwater produced during the 2005–2006 review period represents approximately 117% of this average annual goal. The cumulative volume of groundwater extracted and treated by the Utica systems since the aquifer restoration efforts began at this site in November 2004 represents 92% of the theoretical production target for this period.

Sampling and analysis of the effluent water from the air stripping and spray irrigation treatment units indicated that during the review period these systems functioned at a minimum efficiency of 93% (on the basis of data for individual samples). (Higher efficiency of approximately 99% was calculated on the basis of the average concentration delivered to the wetlands during the review period.) Carbon tetrachloride concentrations in all discharges of treated water at the site were below the permitted maximum target (44.2 μg/L) by roughly an order of magnitude.

Calculations based on the volumes and measured carbon tetrachloride concentrations of the groundwater extracted and treated during the review period indicated that approximately 34 kg (5.6 gal) of carbon tetrachloride was removed from the Utica aquifer.

The total costs incurred by Argonne for operating and maintenance of the aquifer restoration effort at Utica during the 2005–2006 review period were approximately $271,000. Excluding the costs of non-routine repairs and improvements, routine operating costs for the Utica project during this period were approximately $208,000. For comparison, routine operating costs totaled approximately $271,000 in 2004–2005 (excluding the one-time cost of approximately $12,000 for well installation). The lower routine costs in the second year of

operation were consistent with expectations for more efficient operation with increased experience (Argonne 2005).

8 References

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